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oxygen and bind or release it as required. Such a coating is known as a washcoat and consists e.g. of Ce_2O_3 (dicerium trioxide). By means of this washcoat, fluctuations in the air/fuel mixture and the corresponding exhaust gas are thus compensated in the catalytic converter as long as the washcoat has not yet bound its maximum quantity of oxygen or else no more oxygen is bound in the washcoat. However, if these limits are exceeded, the efficiency of the three-way catalytic converter is markedly reduced, resulting in increased pollutant emissions from the internal combustion engine.

In the case of closed-loop lambda control incorporating an oxygen sensor disposed upstream of the three-way catalytic converter, it is known to use the measurement signal of an oxygen probe which is disposed downstream of the three-way catalytic converter and generates a binary measurement signal, to adjust a P- or I-component of the control parameters or a delay time of the lambda controller accordingly as a function of the measurement signal of the oxygen sensor downstream of the three-way catalytic converter. This is also known as trim control. However, it has been found that, despite this measure, particularly in the case of aging three-way catalytic converters, undesirably high pollutant emissions of the internal combustion engine may continue to occur.

A method for operating a three-way catalytic converter is known from DE 101 03 772 A1, wherein said catalytic converter includes an oxygen-storing component which has a minimum and maximum filling level for oxygen. The three-way catalytic converter is disposed in an exhaust gas line of an internal combustion engine. The air/fuel mixture supplied to the engine is regulated in such a way that the filling level of the oxygen-storing component in the catalytic converter is kept within a mean setpoint range between the minimum and maximum

filling levels. Drifting of the filling level out of the setpoint range is checked in a test phase in such a way that the filling level is increased or lowered relative to the instantaneous initial value by short-term reduction in richness or enrichment of the air/fuel mixture supplied to the engine by a certain amount and immediately returning to the initial value by a short-term opposing change in the air/fuel mixture. In the event of a breakthrough of lean or rich exhaust gas through the catalytic converter during the test phase, the air/fuel mixture is briefly enriched or reduced in richness in the form of a correction step in order to correct the air/fuel mixture supplied to the engine.

US 6,253,542 B1 discloses an air-fuel mixture control in an internal combustion engine which comprises a post-catalyst exhaust gas sensor. If the measurement signal of the post-catalyst exhaust gas sensor is outside a predefined acceptable range, a proportional parameter of the control is set as a function of the measurement signal.

Methods for adjusting an air/fuel ratio in an internal combustion engine are also known from DE 100 28 570 A1 and DE 43 22 341 A1, said methods in each case having oxygen sensors which are disposed downstream of a catalytic converter.

The object of the invention is to create a method and an apparatus for controlling an internal combustion engine which ensure low pollutant emissions over a long operating period of the internal combustion engine in a simple manner.

This object is achieved by the features of the independent claims. Advantageous embodiments of the invention are set forth in the dependent claims.

oxygen sensor frequently occurs again and again with associated pollutant emissions, in particular NOX emissions of the internal combustion engine.

By the metering-in of the mass of fuel to be metered-in on a one-time basis, the three-way catalytic converter is placed in a state in which an appropriately predefinable reserve is provided for absorbing or storing oxygen, thereby enabling corresponding fluctuations in the air/fuel ratio in cylinders to be very well compensated by the three-way catalytic converter and quickly ensuring a significant reduction in pollutant emissions.

The mass of fuel to be metered-in on a one-time basis is determined as a function of a gradient of the measurement signal of the post-cat oxygen sensor. The gradient is a very good indicator of the state of the three-way catalytic converter and therefore as to whether a slight or severe oxygen overflow is present. In this way, the stored oxygen remaining in the three-way catalytic converter after metering-in of the mass of fuel to be metered-in on a one-time basis can be very precisely adjusted.

Alternatively or in addition, the mass of fuel to be metered-in on a one-time basis can be determined as a function of a minimum measured value of the measurement signal, while the measurement signal of the post-cat oxygen sensor is characteristic of at least one predefined residual oxygen component. The minimum measured value is a very good indicator of the state of the three-way catalytic converter and therefore as to whether a slight or severe oxygen overflow is present. In this way, the stored oxygen remaining in the three-way catalytic converter after metering-in of the mass of

fuel to be metered-in on a one-time basis can be very precisely adjusted.

In this connection the mass of fuel to be metered-in on a one-time basis can be determined in a particularly simple manner if the measurement signal of the post-cat oxygen sensor falls below a specified first threshold value, the specified first threshold value being suitably predefined.

According to an advantageous embodiment of the invention, the mass of fuel to be metered-in on a one-time basis is predefined such that approximately 50 % of the oxygen storable in the three-way catalytic converter remains after metering-in of the mass of fuel to be metered-in on a one-time basis. In this way, after metering-in of the mass of fuel to be metered-in on a one-time basis, a maximum variability of the air/fuel ratio in the relevant cylinder is possible without any increase in pollutant emissions downstream of the three-way catalytic converter.

According to another advantageous embodiment of the invention, the mass of fuel to be metered-in on a one-time basis is determined from an estimated value of the current oxygen storage capacity by means of a physical model of the three-way catalytic converter. In this way, the stored oxygen remaining in the three-way catalytic converter after metering-in of the mass of fuel to be metered-in on a one-time basis can be very precisely adjusted.

According to a second aspect, the invention is characterized by a method and a corresponding apparatus wherein a mass of fuel to be supplied to the cylinder is determined as a function of a load variable, and a mass of fuel reduced on a one-time basis is determined if the measurement signal of the

post-cat oxygen sensor is characteristic of at least one predefined residual fuel component, namely as a function of the response of the measurement signal.

A corrected mass of fuel to be supplied is determined as a function of the mass of fuel to be supplied minus if necessary the mass of fuel reduced on a one-time basis. An actuating signal for controlling the injection valve is generated as a function of the corrected mass of fuel to be supplied, using the knowledge that, when the measurement signal of the post-cat oxygen sensor is characteristic of at least one predefined residual fuel component, the three-way catalytic converter has essentially stored no more oxygen and thus during operation of the internal combustion engine in this state, even if a known trim control may be present, a so-called breakthrough of the measurement signal of the post-cat oxygen sensor frequently occurs again and again with associated pollutant emissions, in particular CO and HC emissions of the internal combustion engine.

By means of the mass of fuel reduced on a one-time basis, with suitable selection of same a corresponding oxygen excess, relative to the stoichiometric air/fuel ratio, can be produced which then results in a corresponding storage of oxygen in the three-way catalytic converter. There is then provided in the three-way catalytic converter a correspondingly predefinable reserve for absorbing or storing oxygen. This enables corresponding fluctuations of the air/fuel ratio in cylinders to be very well compensated by the three-way catalytic converter and a substantial reduction in pollutant emissions is quickly ensured.

The mass of fuel reduced on a one-time basis is determined as a function of the gradient of the measurement signal of the post-cat oxygen sensor.

Alternatively or in addition, the mass of fuel reduced on a one-time basis can be determined as a function of a maximum value of the measurement signal, while the measurement signal of the post-cat oxygen sensor is characteristic of at least one predefined residual oxygen component.

In an advantageous embodiment of the second aspect of the invention, the mass of fuel reduced on a one-time basis is determined if the measurement signal of the post-cat oxygen sensor exceeds a predefined second threshold value. This is particularly simple.

According to a further advantageous embodiment of this aspect of the invention, the mass of fuel reduced on a one-time basis is predefined such that approximately 50 % of the oxygen storable in the three-way catalytic converter is stored after a mass of fuel, less the reduced mass of fuel, has been correspondingly metered-in.

According to another advantageous embodiment of the second aspect of the invention, the estimated value of the current oxygen storage capacity of the three-way catalytic converter is determined.

Exemplary embodiments of the invention are explained in greater detail below with reference to the accompanying schematic drawings, in which:

Figure 1 shows an internal combustion engine with a control device,

Figure 2 shows a block diagram of the control device,

Figure 3 shows a flowchart of a first part of a program for controlling an internal combustion engine, and

Figure 4 shows a second part of a program for controlling the internal combustion engine.

In the figures, constructionally or functionally identical elements are denoted by the same reference numerals throughout.

An internal combustion engine (Figure 1) comprises an intake tract 1, an engine block 2, a cylinder head 3 and an exhaust tract 4. The intake tract 4 preferably incorporates a throttle valve 6, as well as a plenum 7 and an intake pipe 8 which leads to a cylinder Z1 via an intake duct in the engine block 2. The engine block 2 additionally comprises a crankshaft 10 which is coupled to the piston 12 of the cylinder Z1 via a connecting rod 11.

The cylinder head 3 contains a valve train comprising a gas inlet valve 14, a gas outlet valve 15 and valve operating mechanisms 16, 17. The cylinder head 3 additionally incorporates an injection valve 19 and a spark plug 20. Alternatively, the injection valve 19 can also be disposed in the intake pipe 8.

The exhaust tract 4 incorporates a catalytic converter 22 which is implemented as a three-way catalytic converter.

A control device 24 is provided to which sensors are assigned which detect different measured variables and determine the

Claims

1. A method for controlling an internal combustion engine with an intake tract (1) and an exhaust tract (4) incorporating a three-way catalytic converter (22), and with at least one cylinder (Z1 - Z4) which communicates with the intake tract (1) depending on the position of a gas inlet valve (14) and which communicates with the exhaust tract (4) depending on the position of a gas outlet valve (15), and an injection valve (19) assigned to the cylinder (Z1 - Z4) and which meters fuel in, a post-cat oxygen sensor (37) which is disposed downstream of the three-way catalytic converter (22) in the exhaust tract (4), wherein

- a mass of fuel to be supplied (MFF) which is to be supplied to the relevant cylinder (Z1 - Z4) is determined as a function of a load variable,
- a mass of fuel to be metered-in on a one-time basis (MFF_ADD) is determined if the measurement signal (MS) of the post-cat oxygen sensor (37) is characteristic of at least one predefined residual oxygen component, namely as a function of the response of the measurement signal (MS) of the post-cat oxygen sensor (37), the mass of fuel to be metered-in on a one-time basis (MFF_ADD) being determined as a function of a gradient (GRAD_MS) of the measurement signal (MS) of the post-cat oxygen sensor (37) and/or the mass of fuel to be metered-in on a one-time basis (MFF_ADD) being determined as a function of a minimum value (MIN_MS) of the measurement signal (MS) of the post-cat oxygen sensor (37) while the measurement signal (MS) of the post-cat oxygen sensor (37) is characteristic of at least one predefined residual oxygen component,
- a corrected mass of fuel to be supplied (MFF_COR) is determined as a function of the mass of fuel to be supplied (MFF) and possibly of the mass of fuel to be metered-in on a

one-time basis (MFF_ADD) and
- an actuating signal for controlling the injection valve (19) is generated as a function of the corrected mass of fuel to be supplied (MFF_COR).

2. The method as claimed in claim 1,
wherein the mass of fuel to be metered-in on a one-time basis (MFF_ADD) is determined if the measurement signal (MS) of the post-cat oxygen sensor (37) is below a predefined first threshold (THD1).

3. The method as claimed in one of the preceding claims,
wherein the mass of fuel to be metered-in on a one-time basis (MFF_ADD) is predefined in such a way that approximately 50 % of the oxygen storable in the three-way catalytic converter (22) remains after the metering-in of the mass of fuel to be metered-in on a one-time basis (MFF_ADD).

4. The method as claimed in one of the preceding claims,
wherein the mass of fuel to be metered-in on a one-time basis (MFF_ADD) is determined as a function of an estimated value (OSC) of the current oxygen storage capacity of the three-way catalytic converter (22).

5. A method for controlling an internal combustion engine with an intake tract (1) and an exhaust tract (4) incorporating a three-way catalytic converter (22), and with at least one cylinder (Z1 - Z4) which communicates with the intake tract (1) depending on the position of a gas inlet valve (14) and which communicates with the exhaust tract (4) depending on the position of a gas outlet valve (15), and an injection valve (19) assigned to the cylinder (Z1 - Z4) and which meters fuel in, a post-cat oxygen sensor (37) which is disposed downstream of the three-way catalytic converter (22) in the exhaust tract

(4), wherein

- a mass of fuel to be supplied (MFF) which is to be supplied to the relevant cylinder (Z1 - Z4) is determined as a function of a load variable,
- a mass of fuel reduced on a one-time basis (MFF_RED) is determined if the measurement signal (MS) of the post-cat oxygen sensor (37) is characteristic of at least one predefined residual fuel component, namely as a function of the response of the measurement signal (MS) of the post-cat oxygen sensor (37), the mass of fuel reduced on a one-time basis (MFF_RED) being determined as a function of a gradient (GRAD_MS) of the measurement signal (MS) of the post-cat oxygen sensor (37) and/or the mass of fuel reduced on a one-time basis (MFF_RED) being determined as a function of a maximum value (MAX_MS) of the measurement signal (MS) while the measurement signal (MS) of the post-cat oxygen sensor (37) is characteristic of at least one predefined residual fuel component,
- a corrected mass of fuel to be supplied (MFF_COR) is determined as a function of the mass of fuel to be supplied (MFF) and if necessary minus the mass of fuel reduced on a one-time basis (MFF_RED) and
- an actuating signal for controlling the injection valve (19) is generated as a function of the corrected mass of fuel to be supplied (MFF_COR).

6. The method as claimed in claim 5,
wherein the mass of fuel reduced on a one-time basis (MFF_RED) is determined if the measurement signal (MS) of the post-cat oxygen sensor (37) exceeds a predefined second threshold value (THD2).

7. The method as claimed in one of the claims 5 or 6,

wherein the mass of fuel reduced on a one-time basis (MFF_RED) is predefined such that approximately 50 % of the oxygen storable in the three-way catalytic converter (22) is stored after the mass of fuel correspondingly reduced by the reduced mass of fuel (MFF_RED) has been metered-in.

8. The method as claimed in one of the claims 5 to 7, wherein the mass of fuel reduced on a one-time basis (MFF_RED) is determined as a function of an estimated value (OSC) of the current oxygen storage capacity of the three-way catalytic converter.

9. An apparatus for controlling an internal combustion engine with an intake tract (1) and an exhaust tract (4) incorporating a three-way catalytic converter (22), and with at least one cylinder (Z1 - Z4) which communicates with the intake tract (1) depending on the position of a gas inlet valve (14) and which communicates with the exhaust tract (4) depending on the position of a gas outlet valve (15), and an injection valve (19) assigned to the cylinder (Z1 - Z4) and which meters fuel in, a post-cat oxygen sensor (37) which is disposed downstream of the three-way catalytic converter (22) in the exhaust tract (4), wherein the apparatus has means of
- determining, as a function of a load variable, a mass of fuel to be supplied (MFF) which is to be supplied to the relevant cylinder (Z1 - Z4),
- determining a mass of fuel to be metered-in on a one-time basis (MFF_ADD) if the measurement signal (MS) of the post-cat oxygen sensor (37) is characteristic of at least one predefined residual oxygen component, namely as a function of the response of the measurement signal (MS) of the post-cat oxygen sensor (37), the mass of fuel to be metered-in on a one-time basis (MFF_ADD) being determined as a function of a gradient (GRAD_MS) of the measurement signal (MS) of the post-

cat oxygen sensor (37) and/or as a function of a minimum value (MIN_MS) of the measurement signal (MS) of the post-cat oxygen sensor (37) while the measurement signal (MS) of the post-cat oxygen sensor (37) is characteristic of at least one predefined residual oxygen component,

- determining a corrected mass of fuel to be supplied (MFF_COR) as a function of the mass of fuel to be supplied (MFF) and if necessary of the mass of fuel to be metered-in on a one-time basis (MFF_ADD) and
- generating an actuating signal for controlling the injection valve (19) as a function of the corrected mass of fuel to be supplied (MFF_COR).

10. An apparatus for controlling an internal combustion engine with an intake tract (1) and an exhaust tract (4) incorporating a three-way catalytic converter (22), and with at least one cylinder (Z1 - Z4) which communicates with the intake tract (1) depending on the position of a gas inlet valve (14) and which communicates with the exhaust tract (4) depending on the position of a gas outlet valve (15), and an injection valve (19) assigned to the cylinder (Z1 - Z4) and which meters fuel in, a post-cat oxygen sensor (37) which is disposed downstream of the three-way catalytic converter (22) in the exhaust tract (4), wherein the apparatus has means of

- determining, as a function of a load variable, a mass of fuel to be supplied (MFF) which is to be supplied to the relevant cylinder (Z1- Z4),
- determining a mass of fuel reduced on a one-time basis (MFF_RED) if the measurement signal (MS) of the post-cat oxygen sensor (37) is characteristic of at least one predefined residual fuel component, namely as a function of the response of the measurement signal (MS) of the post-cat oxygen sensor (37), the mass of fuel reduced on a one-time basis (MFF_RED) being determined as a function of a gradient

(GRAD_MS) of the measurement signal (MS) of the post-cat oxygen sensor (37) and/or as a function of a maximum value (MAX_MS) of the measurement signal (MS) while the measurement signal (MS) of the post-cat oxygen sensor (37) is characteristic of at least one predefined residual oxygen component,

- determining a corrected mass of fuel to be supplied (MFF_COR) as a function of the mass of fuel to be supplied (MFF) and if necessary minus the mass of fuel reduced on a one-time basis (MFF_RED) and
- generating an actuating signal for controlling the injection valve (19) as a function of the corrected mass of fuel to be supplied (MFF_COR).